LIGHTNING
AND
Petroleum Storage Tanks

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A Scientific Exposition of the
Manner by which
Lightning Causes Tank Fires
with
Helpful Suggestions *and*
Means of Protection

By WEST DODD, Des Moines, Ia.

PRICE 50 CENTS

A FOREWORD
TO THE PETROLEUM INDUSTRY

There would be no tank fires if you knew how to prevent them, would there?

This little book will tell you why your tanks take fire during thunder storms and how to prevent these fires.

The lessons taught in this booklet are established on fundamental truths and should be scientifically discussed by all who are interested, for the national welfare.

The principles enumerated are the essence of years of observation in the field and of scientific research in the laboratory and are based on unassailable facts.

Hang up the booklet in your office. Some day you will want it.

Made in Oklahoma

SIX SCIENTIFIC MAXIMS RELATIVE TO LIGHTNING PAUSE A MINUTE WITH EACH

ONE

Lightning results from previous electrical conditions and can not occur without these **previous** electrical conditions.

TWO

Lightning can only occur in an electrical resisting medium such as air, wood, etc., but never on a good and sufficient electrical conductor.

THREE

Lightning can not occur within a metallic structure such as a railway train or a steel structural building or a petroleum storage tank.

FOUR

Lightning is not a projectile like a flying bullet, and is never attracted by metal or anything else. Every part of a lightning flash is made at the identical spot you see it.

FIVE

The **previous** electrical conditions that cause lightning operate under intelligent laws and lightning protection can only be attained by aiding these laws to govern the **previous** electrical condition before the lightning flash develops and **not** by trying to catch the lightning flash.

SIX

Electro Static Sparks are ever liable to occur at the contacts of loosely connected metals at the instant of a near lightning discharge.

NINE SCIENTIFIC MAXIMS RELATIVE TO PETROLEUM STORAGE TANKS. THEY WILL BE EXPLAINED AS WE PROCEED. CRITICIZE EACH ONE THOUGHTFULLY IN ADVANCE THEN STUDY THEM CAREFULLY IN THE TEXT

ONE

Petroleum Storage Tanks with properly riveted steel roofs and closed winch boxes are practically immune from lightning danger.

TWO

The Majority of Petroleum Tank Fires are caused by electro static sparks at electrical resisting roof contacts at the instant of a lightning discharge anywhere in the vicinity and sometimes at remote distances.

THREE

Petroleum Storage Tank Fires are never caused by inflammable vapors in the atmosphere away from and above a tank.

FOUR

The sudden change in the Earth's Electrical Field at the instant of a lightning discharge is the occasion for electro static sparks at all electrical resisting roof connections, or loose sheet metal contacts, and all such tanks situated within this electrified earth area are in more or less danger at that instant.

FIVE

Electric Light wires or any other overhead wires leading to a tank greatly endanger the tank from lightning discharges anywhere along the line.

SIX

To seal a Petroleum Storage Tank vapor tight with a non-electrical conducting material affords no lightning protection whatever, but may increase the lightning hazard.

SEVEN

A direct Lightning Discharge at a tank under normal tank conditions will occur at the edge of the tank and preferably at the head of the stair railing.

EIGHT

A Lightning Discharge can only occur at one tank in any tank farm at the same instant, but other tanks are endangered at that instant from electric discharges from their own roofs.

NINE

The Brush Electric Discharge may cause a tank fire before a lightning flash develops.

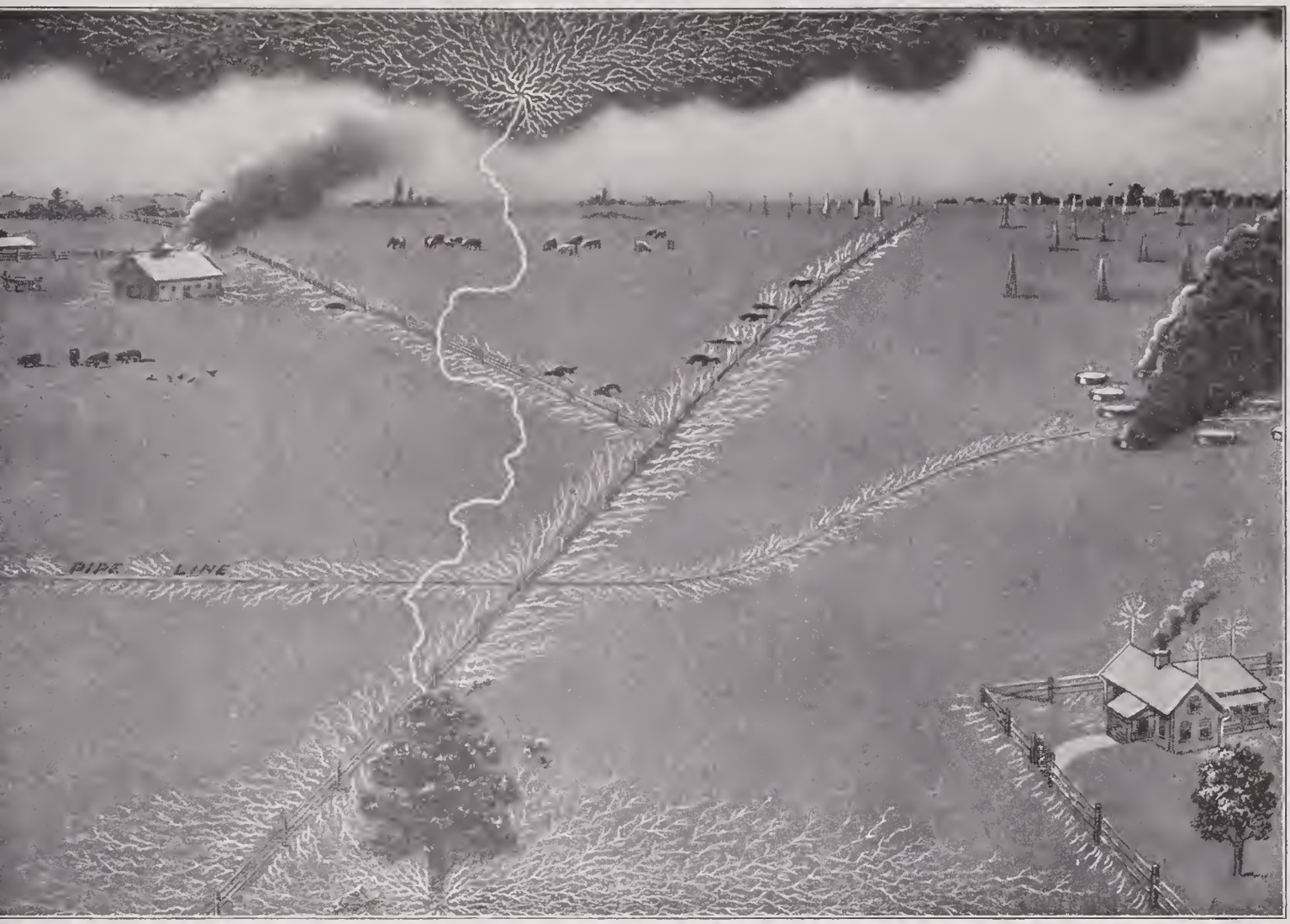

Fig. 1

A Graphical Illustration of the Discharge of the Earth's Electrical Field

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This is an unusually instructive picture.

It tells without words why a lightning flash occurs.

We see a flash between the cloud and the tree.

We see how the cloud at one end and the earth at the other end of the flash give up their electric charges to make the lightning.

We see some dead cattle by a wire fence and some petroleum tanks on fire along a pipe line.

We see a greater electrical intensity on the earth's surface around the tree and along the wire fence and along the pipe line than elsewhere.

The story that follows will tell how and why the tanks take fire at the instant of the flash at the tree.

THE DISCHARGE OF THE EARTH'S ELECTRICAL FIELD
HOW IT CAUSES PETROLEUM TANK FIRES

Scientific knowledge can save tanks.

A lightning flash is not an accident or a freak of nature, but an intelligent creation, and every petroleum tank that burns through lightning causes is a reproach to our intelligence.

That this is true is clearly evidenced by the fact that nearly all tank fires occur on special tank constructions.

Insurance records prove beyond any question that wooden roofed tanks, no difference how well they may be sealed up, are a far more serious lightning hazard than are steel roofed tanks.

If the reason for the excess fires on wooden roofed tanks were understood by the petroleum producers and by the Underwriters these fires would not be permitted, so we may readily conclude every tank fire from lightning causes is a special assessment on our ignorance.

The reasons for these tank fires, however, are quite within our reach and subject to our control, and our theme shall be to render these reasons intelligible and save the tanks.

LIGHTNING AND ELECTRICITY NOT THE SAME THING

The common statement that lightning and electricity are one and the same thing is a little confusing. If we should say fire and coal are one and the same thing, that would not sound very sensible, but it is exactly as sensible as to say lightning and electricity are one and the same thing. We can have coal without fire and we can have electricity without lightning, but we cannot have fire without fuel, neither can we have lightning without electricity. We should think of this intelligently, for in saving the tanks we have to settle with electricity, not with lightning.

Lightning never springs into existence parentless of **previous** electrical conditions, and lightning protection for the tanks is only attainable by knowledge of what these **previous** electrical conditions are doing to the tanks and not by some fool idea of attempting to catch a lightning flash.

WHAT THE PREVIOUS ELECTRICAL CONDITIONS ARE DOING TO THE TANKS

When a cloud is acquiring a charge of electricity **previous** to a lightning discharge, it exerts an electrical influence on the earth's surface beneath it by which this surface takes on an electrical charge of opposite sign. This charged earth's surface is called "The Earth's Electrical Field," which together with the charged cloud constitute the "Previous Electrical Conditions" to which we have referred, and all tanks within this field are subject to this electrical influence.

Before the lightning flash occurs, the electrical charge induced by the cloud is distributed over the earth's electrical field the same as on the cloud, and every acre has more or less of a charge on its surface which is being increased, maintained and bound by the growing charge on the cloud.

A 55,000 barrel tank covers a half acre and the entire charge of that half acre is on the upper surface of the roof of the tank—for this roof is a part of the earth's electrical field—this electrical charge on the roof is acquired gradually or during the period between one lightning discharge and the next.

When the earth's electrical field is suddenly discharged, causing lightning, the half

acre on top of the tank discharges suddenly at that instant, regardless of where the flash occurs and our problem is—**How can we get this half acre charge off the roof without setting the tank on fire?**

This great problem is associated almost entirely on tanks with wooden roofs with or without thin metallic sheathing, or with any container the roof of which has poor electrical conducting continuity.

Before we give detailed reasons for the tank fires we offer this little Dictum:

"If there was no electrical resistance on the tank roofs and no inflammable gases in contact with the outside of the roof, there would never be any tank fires from lightning causes, never any."

We may here state—lightning and electro static sparks can only occur on poor electrical conductors, such as air or other electrical resisting media, and never on a good and efficient electrical conductor, such as metal, and that electricity always seeks to discharge through the path of least resistance.

If all kinds of materials conducted electricity alike there would never be any lightning or any electro-static sparks. Of the hundreds of thousands of various known substances, no two of them conduct electricity alike. Some kinds conducting thousands of times, some kinds conducting millions of times and some kinds conducting billions of times better than others.*† This difference in the electrical conductivity of various things is the true reason why we ever have lightning and tank fires from electrical causes. This knowledge and how to use it rests in the very heart of the fine problem of saving the tanks.

The following nine principles, with the evidence given in each case, will be interesting and instructive to the petroleum industry and to the general public. These principles are statements of scientific facts, all of which can be demonstrated in the laboratory and all of which are supported by reason or by observation in the field.

These principles will command the approval of scientific and technical men, all of whom will agree there is no means of lightning protection for petroleum storage tanks except through knowledge of tank conditions and their ability to govern static electrical discharges.

**The Electrical Markings shown along the wire fences and metallic pipe lines on the earth's electrical field, Fig. 1, are exactly as they appear in laboratory experiments, at the instant of the discharge of a semi-conducting condenser when metallic cords are lying on its surface.*

Ordinary soil is only a semi-conductor, and metallic lines, such as wire fences or pipe lines laid on or in the earth's electrical field, attempt in the same way to convey all of the electricity near them when the earth's electrical field discharges at the instant of a lightning flash.

This explains the intense electrical conditions so dangerous to animals standing near wire fences during lightning discharges, a condition which never exists along wooden fences.

It also explains the serious electrical influence of extended metallic pipe lines, on the tanks with which they are related, at the instant of the discharge of the earth's electrical field.

†For electrical resistance and relative conductance of various substances, see Elementary Lessons in Electricity and Magnetism, page 409, by Sylvanus Thompson.

PRINCIPLE ONE

A Petroleum Storage tank can not take fire from lightning causes on the inside of the tank, for neither lightning or electro static sparks can occur within a metalic structure.

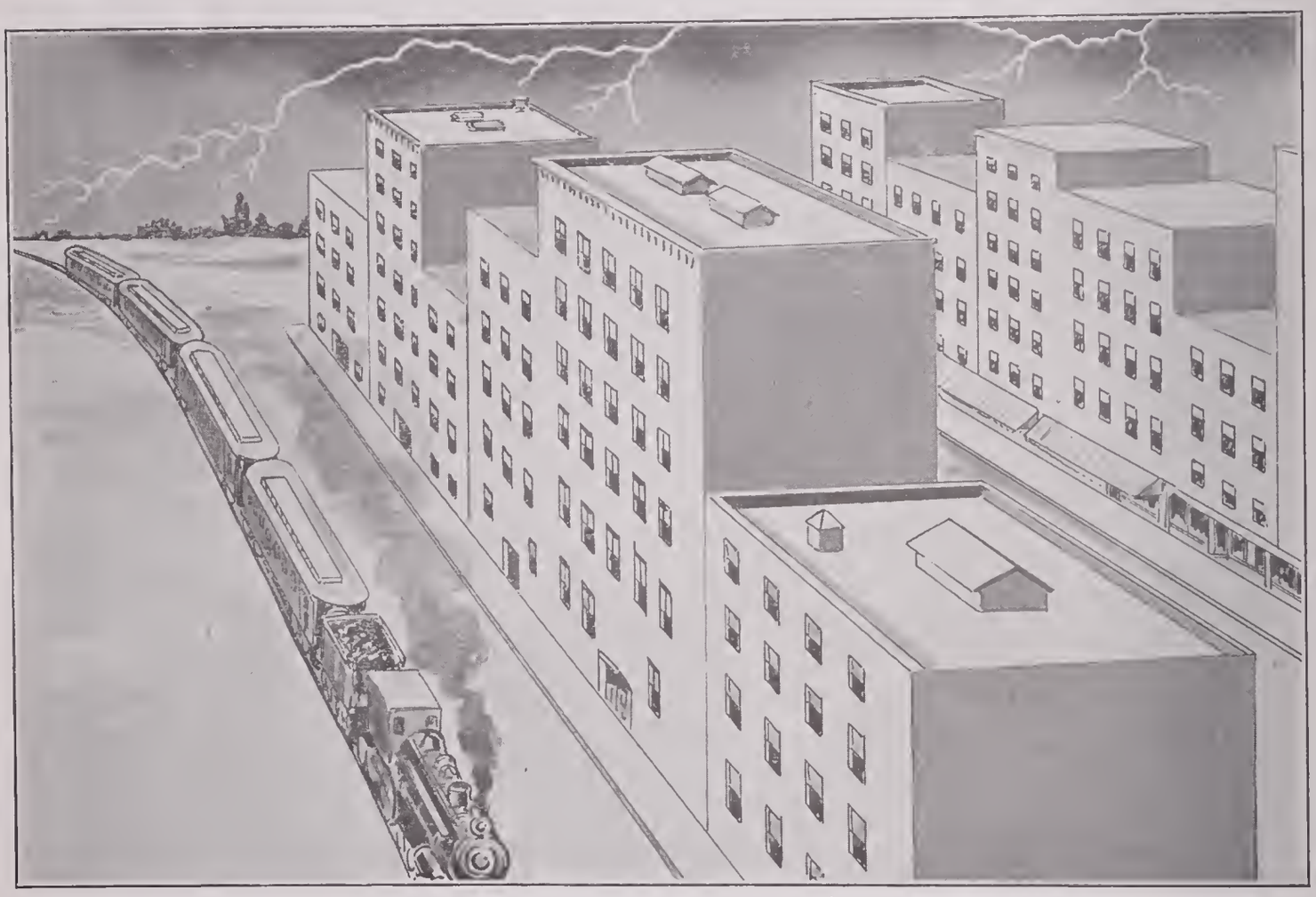


Fig. 2

Immune from Lightning Danger Within

Evidence to Principle One

This principle was first demonstrated and proved by that illustrious scientist, Michael Faraday, more than one hundred years ago and can be verified beyond intelligent dispute by a competent man if he has the proper electrical apparatus.

The reason for the principle is this "Electricity of either sign is self repellent" and because of this, static charges can only exist on the outer surfaces and edges of metallic structures.

That means—The electrical charge on any tank previous to a lightning discharge is all on the outside and none whatever on the inside of the tank; therefore, lightning and electro static sparks due to lightning discharges must always be on the outside of any metallic petroleum tank as well as the outside of any other metallic structure.

The fact that no one was ever injured or shocked from lightning causes within a railway train or within a steel structural building is practical evidence in support of the principle.

The twenty to fifty story skyscrapers of our large cities are immune from lightning influence within because they are steel structural in their framework, and induced electrical charges—being self repellent—can only exist on the outside of any metallic framework and especially on the upper surface and edges, for these are nearest the cloud.

A wooden flag pole or any poor electrical conducting material or a man standing on top of such building might be in imminent danger during a lightning discharge, but all within would be absolutely safe.

Railway coaches and engines are steel cages and for that reason a static electric charge cannot exist within. It might be dangerous on the top of a train during a thunder storm, but not the slightest danger of the mildest electrical shock to those within.

The same is true of a steel petroleum storage tank, all the dangers are on the outside and none whatever within till the fire starts on the outside.

Knowledge of this principle is valuable and should prompt us to intelligent inquiry into the true reason for tank fires during thunder storms, for we can never correct these reasons till we know what they are.

PRINCIPLE TWO

Petroleum tank fires from lightning causes can only start in inflammable gases on the outside and in close relation to the tank roof, and never from inflammable gases high above a tank, which ignite and back fire to one or more tanks.

Fig. 3

Why Does the Torch Not Light the Gas?

Evidence to Principle Two

Experiments of Sir Boverton Redwood, Dr. Du Pre and others, as well as the author, prove that one percent or less of petroleum gas mixed with air is not inflammable.

Avogadro's Law of Gas Diffusion is an accepted maxim of physics and proves that any escaping gas in free air distributes itself uniformly in space.

That means—the ratio of mixture of any gas with free air will decrease in proportion to the cube of its distance from the place of escape, which means—a one percent petroleum gas mixture would be a physical impossibility in free air at any material distance from a tank under any natural conditions of evaporation. Reference to the Ardmore disaster will be found in another part of this book.

The lighter gases in petroleum evaporate most readily, and though these gases are heavier than air their diffusion after their escape is practically the same in all directions if there is no wind. If the wind was blowing at the rate of ten miles an hour—which is less than the average velocity in Oklahoma—diffusion would be so rapid in that direction that an inflammable air gas from a storage tank could only exist within a few inches of the place of its escape.

The illustration, Fig. 3, shows a man holding a flaming torch near a gas flowing pipe in the field, the torch being held where the gas mixture is too thin to ignite because of rapid diffusion. Of course, the pressure and volume of gas flowing from the pipe would determine the inflammable distance where the air is not confined as in a house.

If you have a gas jet in your home try the experiment. Open the jet so the gas will flow freely and see how near you can come to it with a burning match before it will ignite. The experiment will convey an intelligent practical lesson; that is what you want.

PRINCIPLE THREE

A steel roofed tank if gas tight in its roof connections, with intelligent means for its pressure gasses to escape elsewhere than thru the tank roof, could never burn thru lightning causes.

Fig. 4

Close that Winch Box

Evidence to Principle Three

The fact that lightning losses rarely occur with good steel roofed tanks is not due to chance but to good and sufficient reasons. These reasons can be conclusively demonstrated in the laboratory, and justify the assertion that lightning could never cause damage to a steel roofed tank, if it had intelligent care.

Lightning and electro static sparks can only occur in an electric resisting medium such as air, but never on a good electric conductor such as a steel tank, where all the separate metal plates are well connected in continuous electrical contact.

A lightning flash might take place between the cloud and the edge of the tank, but no lightning could occur between the edge of the tank and the ground, as electricity makes no lightning where it has no resistance, and there is less resistance in the immense body of a steel tank than almost anything we can name.

We have an illustration in the case of the electric light in our homes. The light is on an electric resisting filament in a glass globe, but there is neither light nor fire on the conducting wire that leads the electricity to the filament. In like manner lightning can only occur in air or electrical resisting substances.

If a steel roofed tank is gas tight on its roof, lightning can not start a fire there, for the flash is all outside of the tank. (See evidence to Principle One.)

The illustration, Fig. 4, shows a lightning flash at the head of the stair railing of a steel roofed tank. It also shows an open winch box near the stairway through which gas is escaping. A condition like this is too much for any tank, especially a steel roofed tank, as all of the evaporation would come through this opening. Other provision should be made for the gas escape.

When the causes for lightning tank fires are more intelligently considered, and tanks properly conditioned and equipped, there will be few tank fires from lightning causes.

PRINCIPLE FOUR

Tanks with wooden roofs, whether covered with gravel, asphaltum paper, loosely connected sheets of metal or anything else with poor electrical continuity, may take fire at the instant of a lightning discharge even tho the lightning flash is not near the tanks.

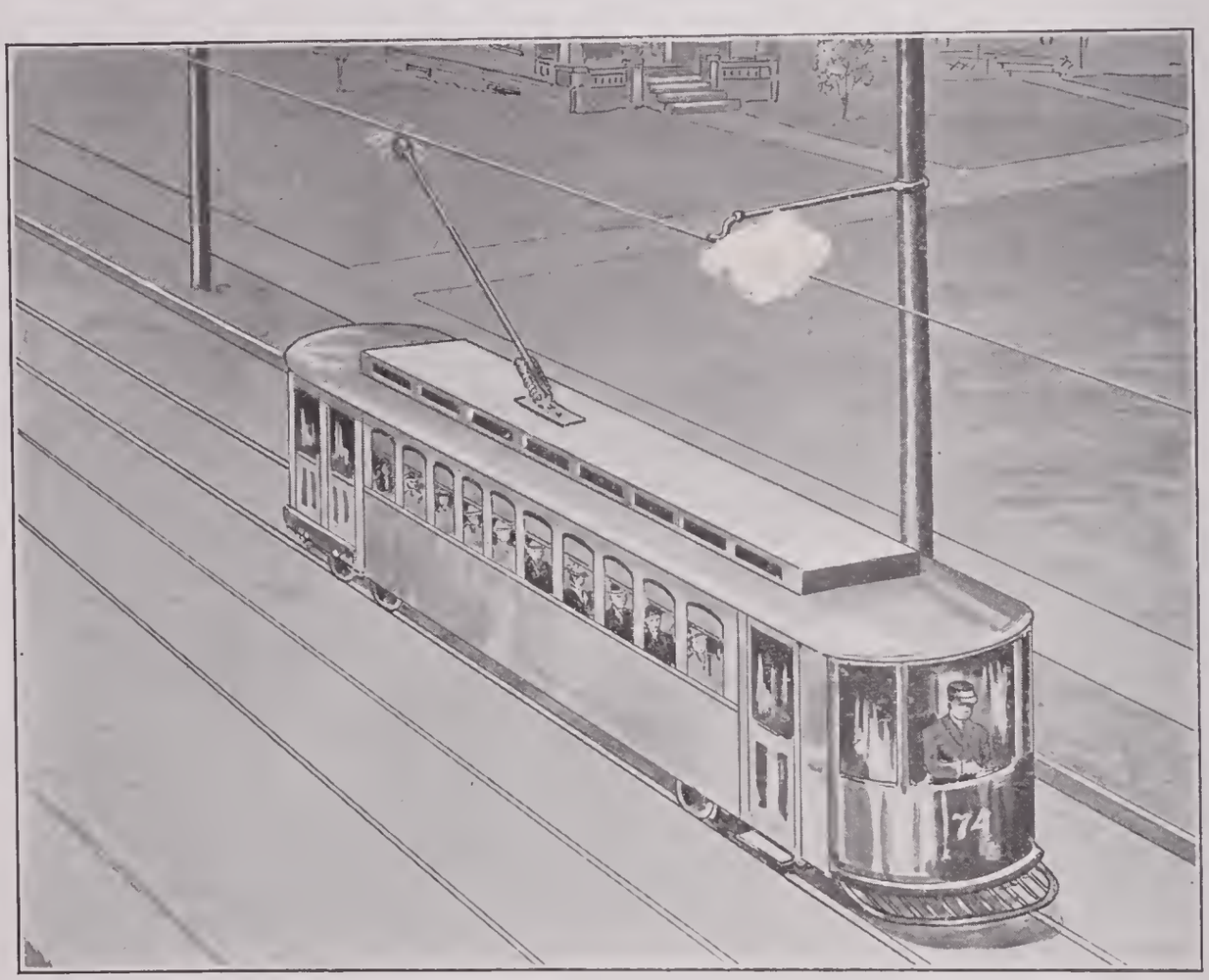


Fig. 5

A Spark at the Trolley Wheel. Why?

Evidence to Principle Four

This principle has a tremendous meaning to the nation as well as to the petroleum interests, as it involves the most serious lightning problem on earth.

The best evidences in support of the principle are the experiences of the petroleum producers and the records of the oil insurance companies.

The principle is laid in a fundamental law of science, which treats of the nature of lightning discharges. This law will be easily comprehended by referring to Fig. 1 and the description of the discharge of the earth's electrical field on pages 5, 6 and 7 of this book.

In this you will learn that lightning is the result of the sudden discharge of electrical conditions that existed on the cloud and on the earth's surface previous to the appearance of the lightning flash. You will also learn that one-half acre of this earth's electrical field is on the top of every 55,000 barrel tank beneath the cloud.

You will further learn that the electrical charge that was bound on each tank roof by the inductive influence of the charging cloud was suddenly released at the instant of the lightning flash and as suddenly returned to earth and that the danger to the tanks from this cause depends entirely on how this previously bound charge got off the roof, and that is the secret we want to explain.

The separate plates of a steel roof are so well riveted together and to the tank rim that any electrical charge on its roof can come off without the slightest interference or resistance. That is the whole secret of the safety of the steel roof, but the thin sheets of metal on a wooden roof are not electrically connected that way. They are attached with nails to the wooden roof and these sheets are soon loosened, due to their co-efficient of expansion in varying temperatures. The roof also has very inferior connection to the tank rim compared with that of a steel roof.

The greatest danger to this class of tanks lies in these loose metallic connections on the roof, for an electrical charge coming off such a roof meets with more or less resistance at these imperfect metallic contacts, and electro static sparks result at the crossings because of this resistance and one or half a dozen tanks may take fire at the same instant dependent entirely on the inflammability of the escaping gas where the spark occurs.

The writer finds through experimental tests that wooden roof tanks without sheet metal take fire only at the edges, but those with sheet metal may take fire anywhere on the roof where gas is escaping. He also finds sparks very frequently occur without causing a fire, but the greater the evaporation the more readily the sparks will start the conflagration.

The illustration here given, Fig. 5, of the electric street car shows a phenomenon with which we are all familiar. It is designed to show what happens between loosely connected metals charged with electricity.

The trolley wheel has bumped from its contact with the charged wire and we observe a spark instantly takes place at the break. If this happened in an inflammable gas a fire would result.

Well, that is exactly what does happen among the tanks at the instant of the discharge of the Earth's Electrical Field unless provision is made to prevent it, for every sheet of metal on the tank roof had a static charge on its upper surface, and when this is suddenly released by a lightning flash anywhere near or far, it means "Danger from electro static sparks in loose metallic connections on the tank roof" the same as you witness at the trolley wheel in the picture.

PRACTICAL EVIDENCE

The following extraordinary record is given to confirm the scientific explanation we have tried to make clear.

At the five critical tank stations, viz., Avondale, Elvista, Sour Lake, Lufkin and Parryman, forty-six tanks were burned during the seasons 1912, 1913, 1914, 1915, 1916 and till June 1917. That was an average of seven tanks a year. In none of these years were less than three tanks burned and in some years as many as twelve.

Since 1917 the West Dodd System of Spark Prevention has been on the tanks at these stations and though three years have passed since these equipments were put on there has never since been a tank loss at either of these stations.

By the rule of expectancy based on the record there should have been ten to twenty more tanks burned at these stations since June, 1917, if the equipments had not saved them.

This practical test is sufficient to prove to a reasonable mind that the fires at these stations had been due to electro static sparks in inflammable vapors between disconnected metals on the tank roofs as the spark preventing system alone is all that is used on any of the tanks at either of these stations, and nothing whatever to guard against a direct lightning flash at a tank.

It is clearly evident a direct lightning flash in contact with a gas leaky roof would start a fire at any of these tanks in defiance of the spark preventing system, but the fact that this did not happen in the last three years is reasonable evidence that electro static sparks had previously done the business.

It is only fair to here state, Elvista has been practically abandoned, but generous allowance has been made in the estimated number of tanks saved by the equipments.

PRINCIPLE FIVE

A direct lightning discharge at a tank is a frequent occurrence and under ordinary tank construction will take place at the edge of the roof and not in the center unless some metallic projection is there.

Fig. 6

The steel roofed tanks A and C can withstand it. The wooden roofed tanks B and D are in danger from electro static sparks

Evidence to Principle Five

From a scientific consideration a tank is a very natural point for the discharge of the earth's electrical field provided cloud and atmospheric conditions were uniform, but the distance between the tank and the cloud is relatively large compared with the distance between the top of the tank and the ground, and cloud formation and atmospheric conditions are ever varying which would almost equalize the chances for the path of least electric resistance between the cloud and objects of equal height unless they were near to each other in which event it would discharge through the best conductor.

To that extent it would choose the tank and discharge at the tank rim and preferably at the head of the iron stair railing.

It is a matter of general observation that lightning at houses or barns occurs at the corners or edges if they have no chimneys or cupolas. If they have ordinary chimneys or cupolas near the center of the roof and not near the ends lightning would still attack the corners or ends of the roof unless there should be tin valleys or other metallic ways on the roof leading to such chimneys or cupolas.

The reason for this is "The induced electricity of either sign is self-repellent" which makes the previous electrical conditions more intense at the extremities.

Laboratory experiments show, a lightning discharge at a tank would occur at the edges even if the center of the roof were three times as high as ordinarily constructed unless there was a metallic projection on the roof.

A metallic pipe four feet high on the roof center would cause the discharge to take place there but if a smooth metallic arched roof, extended twenty feet above said pipe, the discharge would occur at the tank edge or lower edge of the roof.

In illustration Fig. 6 A and C represent well riveted steel roofed tanks. The lightning flash can not harm them for there are no inflammable gases without on the roof and lightning can not get within.

The lightning flash at "C" endangers the wooden roofed tanks "B" and "D" through sparking possibilities at their loosely connected metallic contacts while "A" is spark proof.

"B" and "D" would have no chance of escape whatever if the flash occurred at the edge of their leaky roofs, as the whole lightning discharge is immensely more dangerous than any single roof discharge.

PRINCIPLE SIX

Electric light or other wires extending to a tank are a source of imminent danger to the tank during thunder storms especially to tanks with poor electrical continuity on their roofs.

Fig. 7
A foolish arrangement

Evidence to Principle Six

It would hardly seem necessary to offer any evidence in support of principle six.

Even if one had little scientific knowledge his observation should furnish sufficient evidence to satisfy the validity of the principle.

Years ago before the telegraph companies put ground wires on their line poles, a lightning discharge would sometimes split half a dozen or more poles in a row.

These lessons taught the telegraph companies to put ground wires on every fifth pole which seems to be sufficient to protect their line poles and nothing worse now happens during a lightning discharge on their lines than a few minor sparks in the telegraph office.

This method, however, would not be dependable where a petroleum storage tank is on the line as the tank because of its splendid electrical connection through its pipe lines to the earth's electrical field would take on a super charge because of the charged overhead wire, even if all the poles along the line were metal. This is easily demonstrated in the laboratory by putting an electriscope on top of the experimental tank which demonstrates the previous electrical condition before the discharge takes place and the increased electro static sparking that results at the instant of the discharge.

Furthermore, the line pole on top of the tank is by far the shortest pole and it is placed near the winch box as it carries the reflector—Fig. 7—that throws the light into the tank. If the winch box should be open, as is frequently the case, what could you expect but a fire at that tank if a lightning flash occurred on the line a mile away.

The day is not far distant when the loss of the nation's Petroleum through lightning causes will be considered criminal.

PRINCIPLE SEVEN

Only one lightning flash can occur within the limits of any tank farm at the same instant. Such thing as lightning forking in the air and occurring at two or more tanks during the same lightning discharge is impossible.

Fig. 8

Forty-two cattle owned by Mr. G. H. Kiefer killed by one lightning discharge on his farm in Kit Carson County, Colorado. Insurance paid by the Home Insurance Company of New York

Evidence to Principle Seven

It is difficult to give proof of this principle from observation because lightning, if near, is blinding and no one can see the flash because of its intense and sudden brightness. A chain of lightning can be seen at a distance, but no branching in its vicinity occurs near the ground. If multiple flashes occur they are well separated.

When more than one tank takes fire at the instant of a lightning discharge one of them might or might not contact with the flash, but all the other tank fires would result from electro static sparks due to the discharge of the bound charges on their roofs.

The evidence in support of this principle is purely scientific.

All gases in their normal condition, including air, are the poorest of all conductors. When a lightning discharge opens a path through the resisting air that path for a second or two becomes a good conductor between the cloud and earth and many electrical pulsations occur through that channel during a discharge for the molecules of air along that crooked path have exploded because of an electrical strain, making them ions or electric carriers which make this ionized path a conductor between cloud and earth till the cloud has fully discharged.

It takes tremendous electric pressure to open this path. To this end the cloud unites its electrical power through various branches, though not always visible, while the earth's electrical field being a better conductor than the cloud can focus its forces at the required spot without branches in the air.

The reason then for one main lightning flash at the earth is because one channel through the air is easier to break down than two especially where connected metallic lines extend through the soil.

The illustration—Fig. 8—is interesting. It shows forty-two cattle killed for Mr. Kieffer by one lightning discharge and not by forty-two separate lightning flashes.

The same kind of discharge that killed these cattle could burn forty-two tanks if the conditions were right.

PRINCIPLE EIGHT

A large concrete reservoir is a risky petroleum container during a local thunder storm unless all of the reinforcing metallic fabric within the concrete is skillfully connected before the concrete is put on.

Fig. 9

The 350,000 barrel reservoir "B" at Gainesville, Texas
A concrete Lesson with a Moral

Evidence to Principle Eight

Mystery vanishes in the light of knowledge and here we offer a wee object lesson Fig. 9.

The concrete reservoir should never burn from lightning causes if its metallic reinforcing material is properly connected during its construction, and this is no job for an indifferent workman or a charlatan.

The danger from electro static sparks is even greater than that of the wooden roofed tank unless its metallic parts are intelligently connected.

If the reservoir—roof and all—are two or three feet under moist ground it is safer, for it is in a measure encaged in electrical conducting earth, but even then its reinforcing metals should be well connected everywhere, lest the surface earth dry out and lightning begins before the rain but no conditions justify loosely connecting metallic fabric in a petroleum reservoir.

If all substances conducted electricity alike there could never be any lightning discharges and no tanks would ever burn from that cause, but substances are not made that way and therein lies the danger.

The reader should see page 409 of Elementary Lessons in Electricity and Magnetism by Sylvanus Thompson, to learn something of this difference in electrical conductivity in certain materials.

There are probably 300,000 different kinds of materials known and no two conduct electricity alike and even the same one will vary under different conditions but under any conditions metal is millions of times better conductor than earth and better still when compared with concrete.

The reader should try to absorb the full meaning of the discharge of the earth's electrical field illustrated in Fig. 1 and described on pages 5, 6 and 7 and learn "The top of every tank or reservoir under a charged cloud is a part of the earth's electrical field."

Ordinary soil is not a very good conductor but the metal pipes in the soil which are attached to a reservoir or tank are conductors of the first order and at the instant of a lightning discharge the tanks and reservoirs are more suddenly and generously relieved of their part of the earth's electrical field because of these extended pipe lines, all of which is easily demonstrated in miniature in the laboratory. (See Fig. 1 and foot note on page 7).

In this connection Fig. 9 is interesting. This 350,000 barrel reservoir at Gainesville, Texas, was burned through lightning causes April 16, 1918. It was constructed on the lowest ground in the neighborhood and practically all of it except the roof was beneath the surface level.

There were eight 55,000 barrel steel tanks on the higher ground surrounding it, and a 75 foot metallic flag pole on high ground within 800 ft. of it. None of the surrounding tanks were in any way affected, probably because they had been previously equipped to prevent sparking.

The flash may have occurred at the 75 foot flag pole on the hill but hardly possible at the underground reservoir in the hollow with so many tall metallic structures surrounding it in on higher ground. Experimental research and reason say "It never did."

This reservoir had a roof surface of 2¾ acres. That means 2¾ acres of the earth's electrical field was on reservoir "B" before the flash occurred. Within this concrete roof was 2¾ acres of loosely connected metal fabric, this roof fabric was separated from the fabric in the body of the reservoir as much as six or more inches, where the roof rests on the wall.

When the lightning discharge occurred the 2¾ acres of the earth's electrical field on top of the reservoir discharged at that moment and the metal fabric delivered the goods as far as the resistance gap at the lower edge of the roof. Then came a six-inch flash and an explosion, and Fig. 9 shows the sequel.

It is probable there were many tiny sparks within the concrete any of which could start a fire if in contact with inflammable vapor, but all of which may have been innocent because of their concealment, but in any event there should be a law against these sparks on top of a petroleum tank or reservoir.

Some years ago it is said a 2,000,000 barrel reservoir was burned during a thunder storm at Humble, Okla., and it is said "Other underground reservoirs in Oklahoma were burned in 1917." If this is correct, the evidence will show that concrete reservoirs constructed as described are the most serious of all lightning hazards for petroleum storage.

The writer, however, is quite convinced that the concrete system of storage can be a very safe system and is hopeful this lesson will result in much good to the petroleum interests.

The time is coming and not far distant when "Uncle Sam" will not permit these lightning losses for they have a national as well as an individual meaning.

PRINCIPLE NINE

A very tall metallic tower standing within or near a petroleum tank farm would endanger every tank in the farm during a local thunder storm unless their roofs are spark-proof and the taller the tower the greater the danger.

Fig. 10

THE UNLUCKY 13

This instructive and interesting object lesson was photographed July 30, 1918, on the premises of Mr. D. L. Haffner, in Pickway Co., Ohio

Evidence to Principle Nine

Perhaps the most convincing proof of this principle is the fact that it has been tried by some of the largest petroleum producers and the principle found to be true by the disastrous consequences to the tanks.

The idea was "The tower would keep lightning away from the tanks" and the idea was perfectly correct. If the tower is tall enough a lightning flash could never get near any of these tanks but nothing else could cause more tank fires from electric influences than such a tower.

A tower so tall would be the earth terminal for all lightning discharges within forty rods. That means, "The earth's electrical field would concentrate among the tanks and discharge at the top of the tower.

No lightning would be nearer the tanks than the top of the tower and no inflammable gas would be nearer the top of the tower than the distance to the tanks but there would be a pyrotechnic display on the top of all tanks the roofs of which had poor electrical continuity and their chances of taking fire would depend entirely on the gas mixture among the sparks.

This thought never occurred to those who tried the expensive experiment. They reasoned "Lightning fell down out of a cloud and struck the tanks and the tower would catch it on the way down." Better knowledge would have taught them to attend to the electrical condition of their tanks first and erect the tower afterwards.

The author is inclined to believe these towers or masts did not get a square deal. They at least would insure against a direct lightning discharge at a tank, and while such towers might greatly intensify sparking possibilities on poorly connected tank roofs these miniature induced charges on the tank roof are very much easier to control than would be the whole earth's electrical field through a lightning discharge at a tank. Experimental failure, however, should help to clear the way for the truth, for victory is attainable through knowledge of the facts.

The illustration Fig. 10 shows what happened to the "Unlucky 13." It is hardly a parallel case to our principle, but it is evident "that tree tower was a bad thing in the center of that group" and it carries a suggestion that a tall tower among the tanks would have a similar meaning unless their roofs were spark proof.

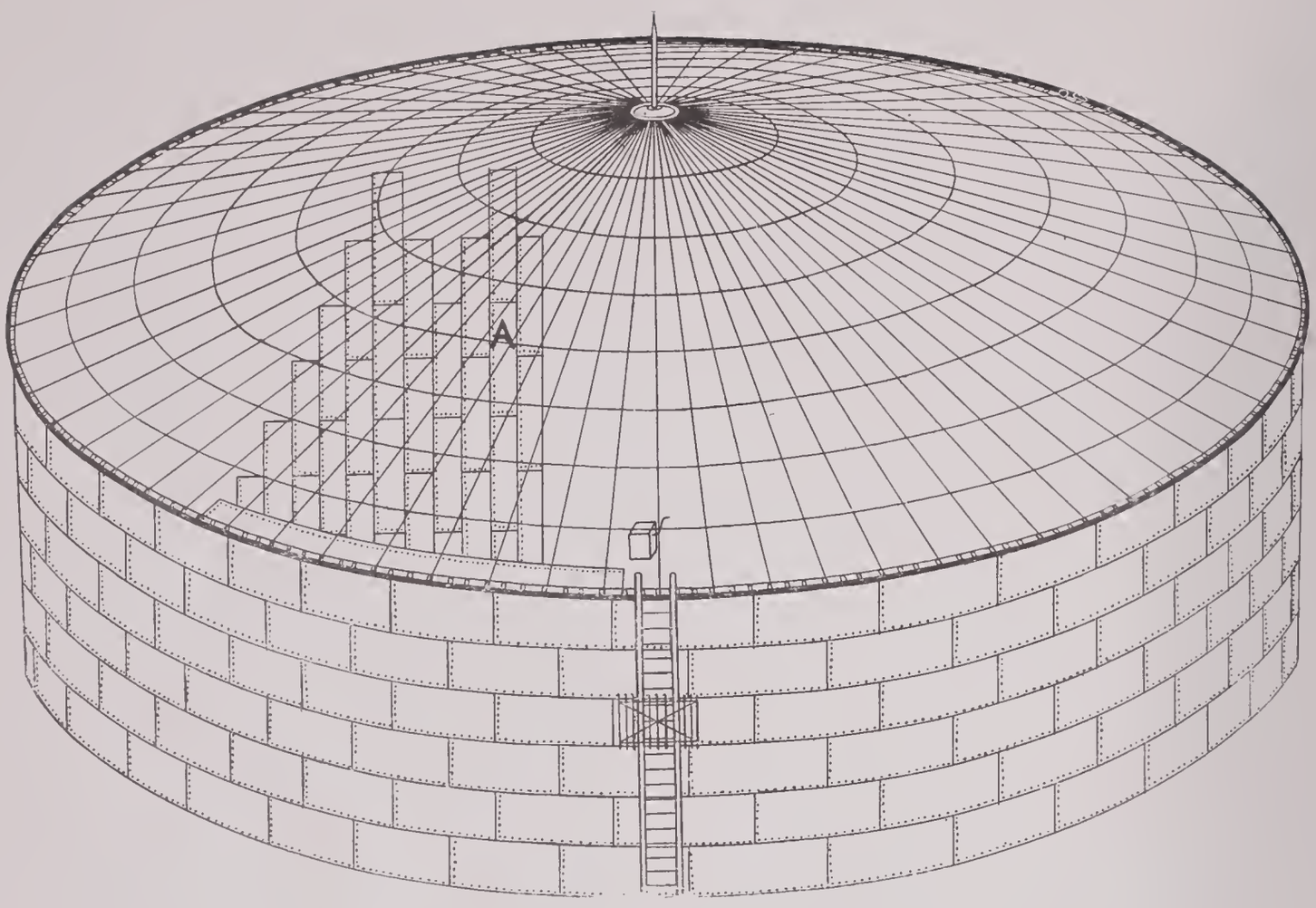


Fig. 11

The West Dodd Tank Protector
Illustrating the equipment of a 55,000 barrel tank

8 Concentric Copper Cables on the Roof.

64 Radial Copper Cables connected electrically every six feet to the tank rim, also at every crossing of every concentric copper cable, also to the large brass cap at the peak of the roof.

1,000 or more electrical connections of the copper cables to the various loosely connected metallic sheets and pipes on the roof to neutralize sparking possibilities between the sheets.

128 Cap Screw connections on all sheet metal roofs where sheets are not riveted or poorly riveted to the tank rim.

A sharp copper point in the brass plate at the peak of the roof to prevent a discharge at the tank rim and silently reduce the electrical intensity at the tank previous to a lightning discharge.

It is relatively inexpensive.
It will not deteriorate.
It costs nothing to maintain.

TO THE PETROLEUM INDUSTRY AND THOSE INTERESTED

In the foregoing nine principles we have told you what we know to be true relative to tank fires from lightning causes which we hope you have found interesting and instructive and you have.

To prevent a tank fire is much better than to permit the fire and extinguish it after it has done thousands of dollars of damage and our theme now is to tell how these lightning losses may be prevented.

The first essential to intelligent means for tank protection is knowledge of why they take fire. The statements in the nine principles given are dictums of science which briefly convey this knowledge. The evidence which follows each principle is an effort to prove the principle is sound.

From these principles we learn that electro static sparks during lightning discharges are the most prolific source of tank fires and that these sparks occur between unskillfully connected metallic parts on a wooden roof or at the contact of a wooden roof with the tank rim.

With this knowledge we can approach the problem of tank protection intelligently, without this knowledge any attempt at protection is puerile and futile and the tanks will continue to burn.

Based on this knowledge we herewith exemplify a system developed by the author by which tanks with roofs having poor or discontinuous electrical conductivity may be saved from fires due to lightning discharges.

THE WEST DODD LIGHTNING PROTECTION SYSTEM FOR PETROLEUM STORAGE TANKS

The illustration Fig. 11 is designed to show a net work of copper cables electrically connecting every sheet of metal on the roof of a 55,000 barrel tank to every other sheet and to the system, also electrically connecting the roof and every part of it to the tank rim in sixty-four separate places about six feet apart.

The sixty-four radial conducting copper cables which connect the roof electrically to the tank are also electrically connected to the concentric girdling copper cables on the tank roof, also to the brass plate in which the point is electrically attached. The object being to have every piece of metal on the roof so well connected that electro static sparks can not occur any more than on a well connected steel roof.

"A," Fig. 11, represents a section of sheet metal on a wooden roof, showing how each metal sheet on the roof comes into metallic union with the system.

So many connections to the tank rim would not be necessary if the various sheets of metal on the roof were not subject to such variations of contact due to their co-efficient of expansion in changing temperatures.

The evidence given to principle four indicates these sixty-four connections have been sufficient to prevent electro static sparks under any normal electrical tank conditions.

THE FUNCTION OF THE POINT

Without the point a lightning discharge could occur at the tank rim among the inflammable gases—Principle Five. With the point the flash could not occur at the tank rim but at the point fifty feet away from the tank rim.

This is not because the point attracts the lightning. The belief that anything attracts lightning is an absurdity.

Lightning results from previous electrical conditions and these electrical conditions are more intense at an upright point than anywhere else, because a point has little surface.

If your eyes were big enough so you could see the air, the function of a point would appear simple enough. The air is made up of minute grains, called molecules, well separated from each other and in eternal motion, but you can not see them.

Before the earth's electrical field and the cloud are ready to discharge through a lightning flash the molecules of air in countless trillions are attracted to the supercharged point and each takes on an electrical charge from the point and flies away with it. This rush of air molecules from a charged point is called the "Electrical Wind" and in laboratory experiments is strong enough to extinguish a burning match or spin a pointed wheel. It is also luminous in the dark, reference to which appears under the title, "Saint Elmo's Fire."

These charged molecules are also called ions, and ionized air is a better electrical conductor than any other air, and that is why the flash occurs at the point, from which we may observe. Nature works intelligently and asks for intelligent consideration.

If these ions could fly away with the charge rapidly enough it would prevent the flash at the tank entirely, but in any event they reduce its intensity as well as dictate the place for the lightning flash if it has to be at the tank.

The system can be used either with or without the point. Without the point it is only a spark preventer, with the point it is a spark preventer and also deals with the greater problem of the direct discharge.

WOULD THIS SYSTEM GIVE ABSOLUTE LIGHTNING PROTECTION UNDER ANY AND EVERY POSSIBLE CONDITION?

That is a fearful question to apply to a petroleum storage tank, but we may as well face the issue squarely and say "Absolute" is probably too strong a word to use with the terms "Any and every possible condition."

We confess it is easier to save a tank from the discharge from its own roof surface than if the discharge from the whole earth's electrical field passed through it, as would be the case if the flash was at the tank.

The great majority of tank fires seem to be due to electro static sparks on their roofs at the instant of a lightning discharge elsewhere, as evidenced in principles four and nine and protection to this class can reasonably be brought under the term "Absolute" but we could not speak without qualifying terms on the minority class.

Points were not used on the tanks specified in the evidence to principle four and elsewhere. These were left off after some discussion with those interested to learn to what extent electro static sparks had caused the previous enormous losses at these stations, with full knowledge a direct lightning discharge through any of these tanks would in all probability start a fire in defiance of the spark preventer, and the fact that not a lightning loss has occurred at either of these stations since they were equipped is reasonable assurance the majority of all tank fires are preventable, absolutely.

A direct lightning discharge through a tank the roof of which has loose metallic sheets in near but imperfect contact, is a different proposition, for when the electricity from every other tank roof as well as the surrounding country has to meet the cloud conditions through a single tank, there is danger of an overflow causing sparks at some of the near but loose connections of the sheet metal and we frankly admit that is where "Absolute" may not appear with integrity, even though no tank has yet been lost where points have been applied. It is here, however, the benefits of a properly erected point have great value in either preventing a lightning discharge at the tank or reducing its intensity so the sixty-four copper cables attached to the tank rim every six feet and electrically attached to every sheet of metal on the tank roof may be able in the majority of this minority class to save the tanks.

It has occurred to the writer that the tower mentioned in principle nine is not a fool idea if the job is intelligently finished for while it might cause additional discharges in that vicinity, it would not be difficult to make the surrounding tanks safe. The six-foot point on the peak of the tank, however, would in no way cause additional discharges, but would minimize them and would prevent them from occurring at the tank rim. A pointed tower or mast would also minimize the lightning intensity, but not prevent sparking on poorly arranged roofs.

Thus far we have given a scientific exposition of how and why lightning causes tank fires and with knowledge of these causes have worked out a means for their protection and for which we offer the following guarantee.

Guarantee

If any tank equipped with the West Dodd System of Lightning Protection, with or without the point, should burn or be otherwise damaged by lightning within five years from date of its equipment the price paid to them for such equipment shall be promptly refunded.

As evidence of good faith in this guarantee we offer the following:

PEOPLE'S SAVINGS BANK

CAPITAL, SURPLUS AND PROFITS $340,000.00

THIS INFORMATION IS GIVEN IN CONFIDENCE
AND WITHOUT PREJUDICE OR RESPONSIBILITY
TO THIS BANK OR TO THE WRITER

Des Moines, Iowa, February 17, 1920.

TO WHOM IT MAY CONCERN:

We are pleased to introduce to you the West Dodd Tank Protector Company who are valued clients of this bank and whom we believe are thoroughly reliable and responsible for any obligations they may make.

Each member of this Company is well and favorably known to us, their record being one of great success and achievements.

The scientific achievements of Professor West Dodd, who is the head of this Company, are favorably known throughout the nation and we feel it is no exaggeration to say that if petroleum tanks can be protected and saved from loss by lightning, this Company is equipped to perform this good work.

Any courtesies extended to this Company will be greatly appreciated.

Yours very truly,
C. H. MARTIN,
President.

IOWA NATIONAL BANK

CAPITAL, SURPLUS AND PROFITS
$2,000,000.00

Des Moines, Iowa, February 21, 1920.

TO WHOM IT MAY CONCERN:

We have been personally acquainted with Prof. West Dodd, the inventor of the West Dodd Tank Protector, for a great many years. We know him to be a very high-grade, scientific man in his line.

We are also acquainted with all the other members of his firm. Their phenomenal success and financial responsibility are established on a foundation of strict integrity and scientific merit.

The researches of Prof. West Dodd along all lines of lightning protection, are of recognized scientific value, and we believe no one in the country better qualified to save the nation's petroleums from destruction by lightning than the West Dodd Tank Protector Co.

We commend them highly to every one.

Very truly yours,
GEO. A. PEARSALL,
Vice President.

GEP S

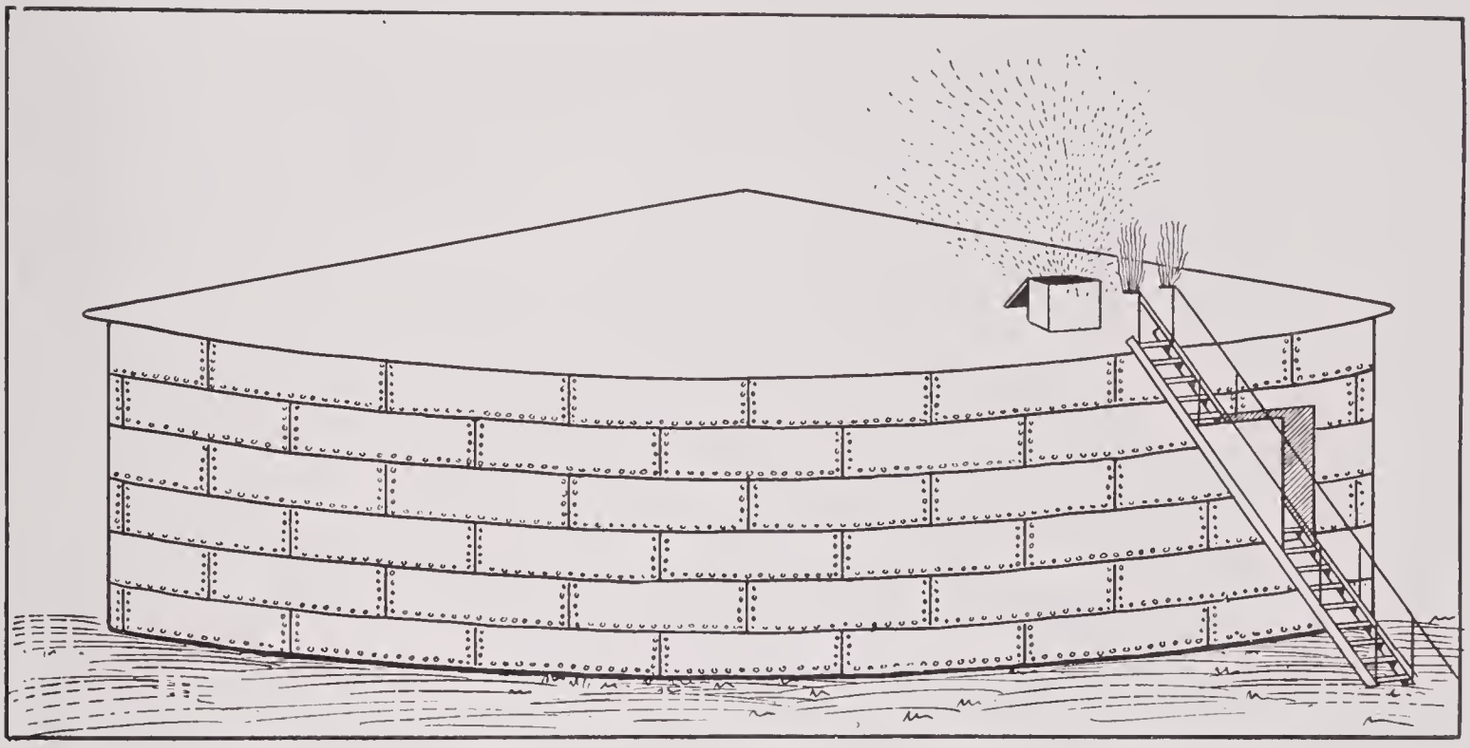


Fig. 12

The Brush Discharge

A possible and unsuspected source of some tank fires is the Brush Electrical Discharge also known as St. Elmo's Fire.

This usually occurs in a humid atmosphere during rapid cloud formation and is a continuous discharge of electricity from the region where it appears. It is quite observable in the dark and has the appearance of a bluish pink flame from one to six inches long, and many continue for some minutes with a sort of hissing sound.

On tanks it is most likely to appear at the top of the stair railing or other outer prominences or edges, but not at the center of the roof unless there are metallic prominences there.

This phenomenon is more common on the ocean than on the land because the electrical resistance of sea water is much less than that of ordinary soils. The earth's electrical field on the ocean can thus localize or focus its electricity more readily at any spot

to accommodate the cloud and stream off in a brush of ions from the crest of a wave or the rigging of a vessel.

A well authenticated instance of the brush discharge occurred on Empire Tank No. 7 at Gainesville, Texas, about 2 o'clock on the morning of April 12, 1918. Mr. Necessary, the gauger, was on the tank at that hour when he heard a sound which he described as "The crushing of dry straw" and looking around saw two flames on top of the stair railing. The flames struck him with terror as he expected the tank to instantly explode and he rushed off between the two electric flames and down the stairs and kept going till he was safely outside the fire wall.

The author has performed many laboratory experiments with the brush discharge and does not find it as hot as it looks. In these experiments it failed to ignite inflammable gas at the points where the brush was discharging but the experimental wooden roofed tanks used readily took fire elsewhere while the brush was discharging.

The brush discharge from a field tank, however, is voluminous in comparison with any laboratory tests, and the conclusion is irresistable that it is not a desirable thing on a petroleum storage tank with poor electrical roof connections.

This discharge is illustrated at the top of the stair railing, Fig. 12, in the vicinity of an inflammable air gas at an open winch box. The writer is not classifying this with the foregoing principles as he is not prepared to say it is as dangerous as it looks, but will confess he would not care to be on top of a tank during the performance.

Empire tank No. 7 had previously been equipped to prevent electro static sparking on the roof, otherwise the tank might have been destroyed and Mrs. Necessary a widow.

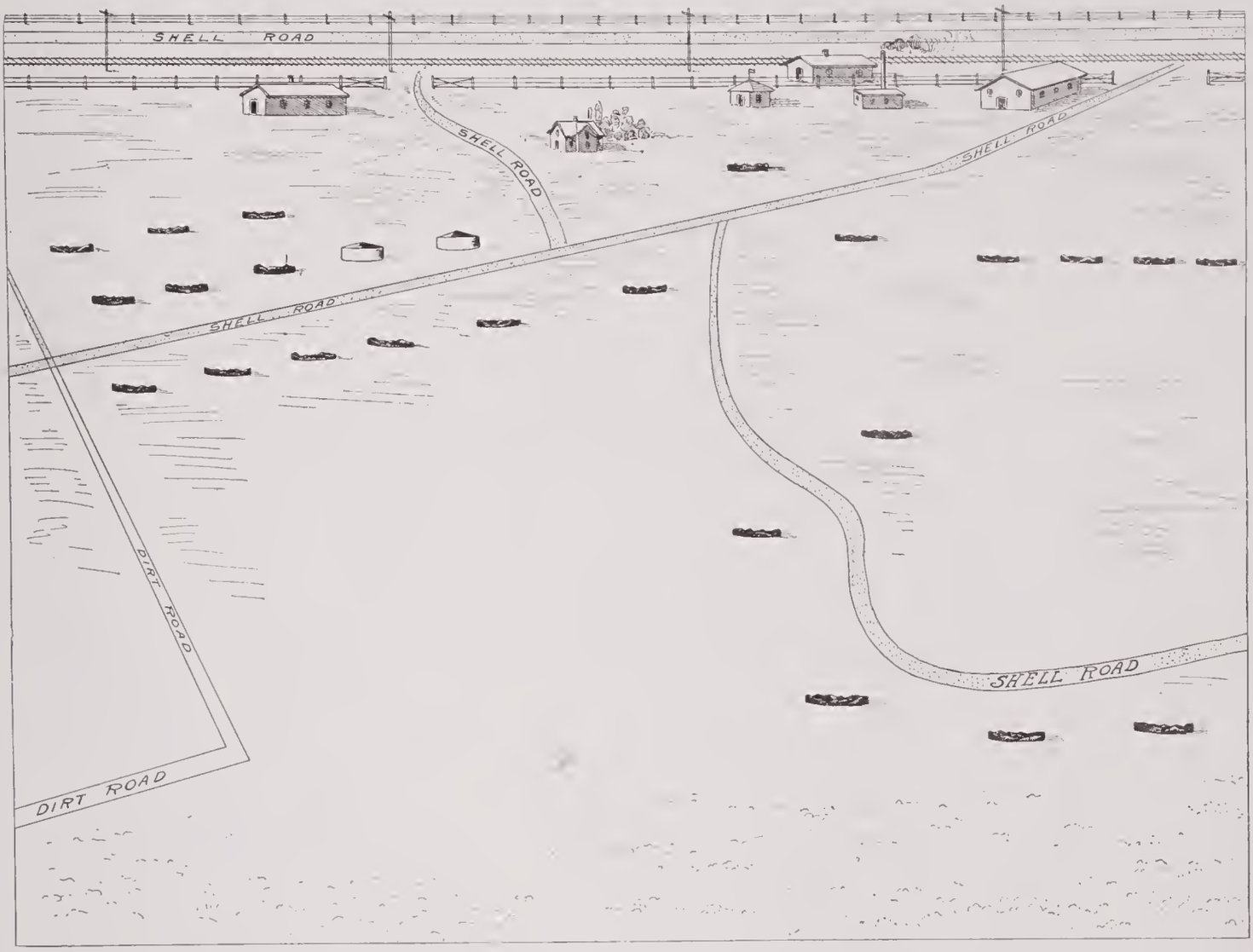


Fig. 13

THE RUINS AT ELVISTA

This exceedingly interesting picture, Fig. 13, has a lesson with a tremendous meaning.

Twenty-three out of twenty-five large wooden roofed tanks have been here burned by lightning.

Nearly all wooden roofed tanks in adjoining territory have gone the same way.

The writer believes the reason for the excess loss to wooden roofed tanks in this region is due to the salty conditions of the Elvista soil.

Salty and alkali soils have much less electrical resistance than ordinary soils and for that reason the earth's electrical field responds more readily to a lightning discharge, thus causing a more intense and sudden change in the electrical potential on a tank roof.

Pure distilled water has millions of ohms of electrical resistance and is rated as an insulator, while ocean water has only about 30 ohms of electrical resistance and is a fair conductor. Soil mixed with fresh water is only a partial conductor, but mixed with salt water is a good conductor.

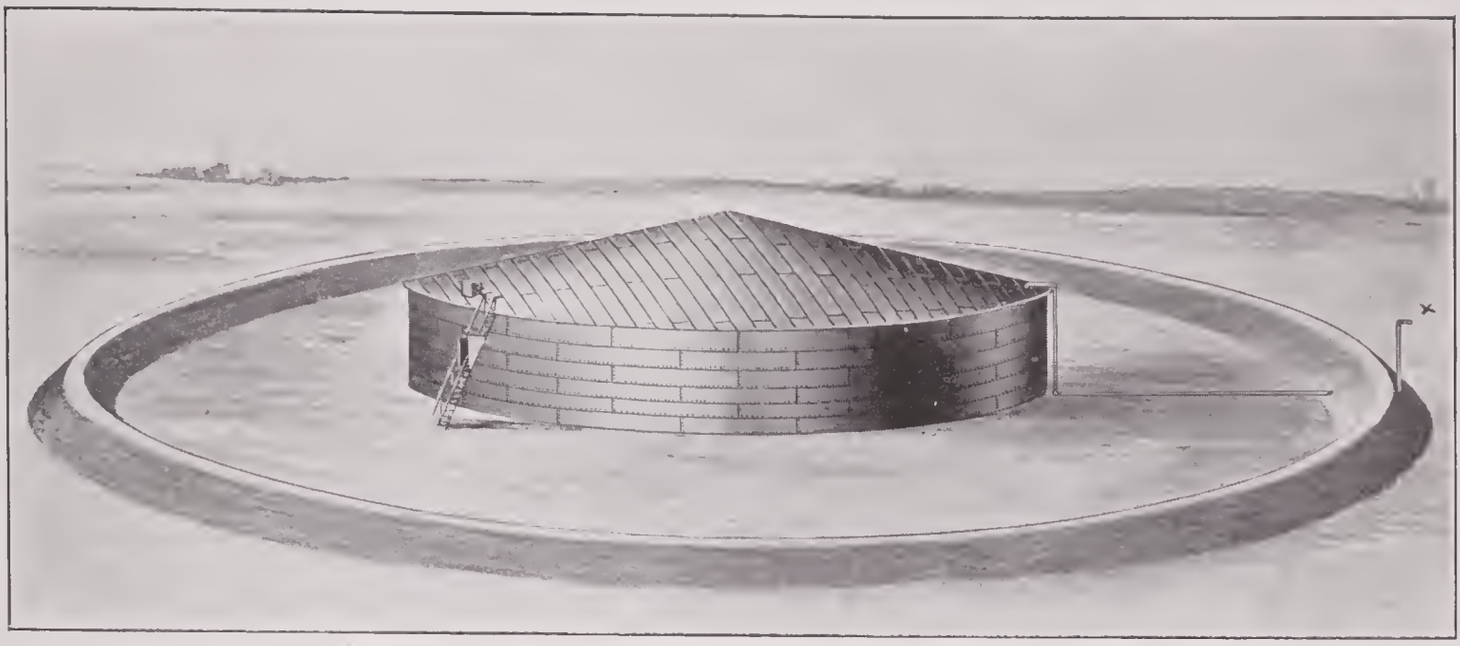
The writer has tested the electrical resistance of the soils at Elvista, Sour Lake, Lufkin, Parryman, Healdton, Cushing, Tulsa, and Ponca City, and while these tests were not very satisfactory they did show that the greatest tank losses were on soils with the least electrical resistance.

Experiments in the laboratory clearly demonstrate that tanks with interruptions in their roof electrical conductivity give far more intense electro static sparks if they are on a good electrical conducting field.

If there was no electrical resistance on the tank roofs they would do no sparking, so it would seem steel roofed tanks or roofs without electrical resistance could withstand Elvista or similar soils.

It is fair to state that experimental tests by the author indicate heavy fuel oils do not readily take fire in a tank from these sparks unless the contents are much agitated as might be the case when a tank is being filled, but there is no reason why they should be given any such opportunity.

What burning petroleum from a boiling over tank did to railway at Elvista



The bird has a happy home in the end of the breathing pipe

CONDITIONS OF THE SEALED TANKS

The roof of a petroleum storage tank should not be sealed gas tight unless ample provision is made for the free passage of gas out and in.

If a gas tight empty tank was filled with any liquid of any kind from a pipe entering the tank, the compressed air or other gas within would break through somewhere before the tank was full. If the same tank was full of any liquid and then all pumped out, without any air getting into the tank, the external air would crush in the walls of the tank before it was empty. To a thinking mind this assertion needs no proof but it indicates the necessity of some intelligent means of letting gas out or in the tank as it is being filled or emptied.

The author has inspected many tanks in which a breathing pipe was used through which the gas pressure within the tank was presumed to be equalized, but in nearly all cases found it inefficient and gas under pressure steaming from the sealed roofs.

The failure in these numerous cases seemed to be associated with two causes; one the breathing pipes were too small; two, the gauze in the end of the pipes at the fire wall was too small and more or less clogged up.

Birds had their nests in the ends of some of these pipes and spiders their webs across the ends of some, and the sealed tank roofs leaking gas under the strain within.

Tanks in this condition are much more dangerous during lightning discharges than if not sealed, for the air gas mixture within is richer in hydro carbon molecules than if the tank had never been sealed and more liable to take fire from electro static sparks.—This is demonstrable in the laboratory.

The writer believes the breathing pipes should be larger and terminate near the ground well within the enclosing earth wall and should have a wide opening with gauze encased, all of which could be encaged for its protection. In this way the sealed roof would be of some value, otherwise, it adds to the danger of the tank.

Of twenty-one large tanks burned in Texas, Oklahoma and Kansas in 1917, seventeen of them are reported to have been sealed with a non-electrical conducting asphaltum material. The gases within these tanks that otherwise would have been less inflammable were conserved by a process of sealing to a dangerous inflammable mixture without proper means of escape and left to the test of electrical discharges with results as stated.

Kerosene evaporates very slowly under any weather conditions (see table on page 39) and the best way to endanger a kerosene tank is to seal it with imperfect means of gas escape elsewhere and then agitate the kerosene such as in filling, then the kerosene tank is as dangerous as any.

These observations are no reflection on sealing tanks, but are a reflection and a condemnation of sealing a tank with no sensible plans of letting the gas out or in as may be required.

Kerosene gases are very heavy and do not diffuse as rapidly as gasoline. You can pour them from one dish into another like water if in a closed room and they will remain inflammable after several pourings.

Kerosene is more dangerous in ocean transportation than in storage tanks surrounded by free air. If these vapors escape in the hold of a vessel where there is little ventilation they will flow on the lower places like water making a dangerous air gas, and some time later a lighted match will finish the job. Various instances of this kind are reported by Sir Boverton Redwood and Dr. Du Pre in Redwood's splendid treatise on Petroleum.

SHOULD PETROLEUM STORAGE TANKS HAVE SPECIAL METALLIC GROUNDINGS FOR LIGHTNING PROTECTION?

The answer to this question is **NO.**

This foolish question would not appear here only for the fact that metallic groundings to the tanks are generally recommended as a prime necessity. The recommendation may be well intentioned, but better knowledge of tank conditions and the nature of lightning discharges would deal with vital facts and never recommend anything of the kind.

To drill holes in the tank wall and connect to earth with a few fence wires or anything else is absurd in view of the knowledge that a half acre of metallic tank surface is already in the soil in addition to miles of heavy pipe line in the earth and attached to the tank.

There is nothing on earth so well grounded as a petroleum storage tank, and it can be demonstrated experimentally there would be less danger to a tank if it was not so well grounded.

When the earth's electrical field is discharged the pipe lines attached to the tank cause a greater and more sudden electrical variation on the tank roof than could be otherwise, Fig. 1, and the greater this variation the more intense the electro static sparking on the roof.

A 55,000 barrel tank near Ranger, Texas, was burned through lightning causes in May, 1920. This tank was sitting in a pond of water at the time and the whole country flooded, pipe lines and all. Could anything be better grounded?

We may here observe, of the hundreds of thousands of steel petroleum storage tanks set in masonry in the cities of the United States and elsewhere, we have no record of a lightning loss or damage in a single instance and they have no metallic groundings whatever.

With this knowledge in mind who would challenge the assertion that field storage tanks, if they could be arranged the same way, would be exactly as safe from lightning if their lids were put on properly.

What the petroleum producers need is knowledge of their tank conditions, based upon adequate facts, then treat these conditions intelligently and the tank troubles will end.

An Interesting Petroleum Table

The Dangerous Petroleum Fractions

1 Petroleum Members	2 Number of Atoms in Molecules	3 Relative Sizes of Molecules	4 Relative Weight to Air	5 Boiling Point Fahr.	
METHANE	$C\ H_4$	○	½	-263°	Gases at ordinary temperatures
ETHANE	$C_2\ H_6$	○	1	-135°	
PROPANE	$C_3\ H_8$	○	1½	- 49°	
BUTANE	$C_4\ H_{10}$	○	2	+ 32°	
PENTANE	$C_5\ H_{12}$	○	2½	98	Gasoline
HEXANE	$C_6\ H_{14}$	○	3	156°	
HEPTANE	$C_7\ H_{16}$	○	3½	208°	
OCTANE	$C_8\ H_{18}$	○	4	256°	Kerosene
NONANE	$C_9\ H_{20}$	○	4½	300°	
DECANE	$C_{10}\ H_{22}$	○	5	343°	
UNDECANE	$C_{11}\ H_{24}$	○	5½	381°	
DODECANE	$C_{12}\ H_{26}$	○	6	417°	
TRIDECANE	$C_{13}\ H_{28}$	○	6½	435°	
TETRADECANE	$C_{14}\ H_{30}$	○	7	485°	
PENTADECANE	$C_{15}\ H_{32}$	○	7½	518°	
HEXADECANE	$C_{16}\ H_{34}$	○	8	549°	

Fig. 14

This is a very instructive table.

Look it over carefully in advance.

In column 3, "Sizes," is used for Masses.

The text will explain it in detail.

Lightning and Petroleum Storage Tanks

We have told you about the discharge of the Earth's Electrical Field and its serious relation to certain classes of petroleum storage tanks. The problems we have tried to explain have been worked out scientifically in field and laboratory and we hope you have found them interesting and instructive. The following story will tell you some interesting things about petroleum and things that have a direct bearing on the burning of the tanks.

THE CONSTITUTION OF CRUDE PETROLEUM

Crude Petroleum is a mixture of about thirty-two different kinds of hydro-carbon compounds and that means—it gives off about thirty-two different kinds of inflammable gases.

The first sixteen of these various hydro-carbon factors are all we need to consider and we give their names and some of their characteristics in the very interesting table, Fig. 14, which we shall proceed to explain.

The first four members of our table are exceedingly volatile under any weather conditions and seldom more than a trace to a small percent of them ever reach the storage tank.

The Gasoline Group comes next. These embrace from three to six of the next lighter members and together with whatever of the first four may be held in solution are the chief tank burners.

The Kerosene family include the other members of our table. The vapors from kerosene are twice as heavy as those from gasoline, and so do not vaporize nor diffuse as rapidly. The lightning hazard is not as great as in gasoline, but very dangerous conditions can be created with the heavy vapors of Kerosene.

The other sixteen members not named make lubricating oils, vaseline and greases and need not enter into our considerations, for lightning damage due to these fractions is very remote.

The second column shows the number of atoms of carbon and hydrogen which unite to make a molecule of the member it represents. This column should be thoughtfully compared with the relative sizes of the molecules in column three, for it is trying to tell you something you should know in order that you may reason why some of the vapors of crude petroleum are heavier than others.

The third column shows the relative sizes of the molecules of the different petroleum members given and not their real sizes, for the largest molecules are not visible in any microscope.

A molecule is the smallest conceivable particle of any substance, and when matter is in liquid form, as in crude petroleum, its molecules flow through and among each other near together, while in gaseous form they are relatively far apart, for a cubic inch of liquid petroleum will make a cubic foot of gas, more or less, dependent on which member we may be considering.

There is a law—Avogadro's Law—governing all gases of every kind, which states, "Equal numbers of molecules will occupy equal volumes of space regardless of the sizes

of the molecules." By looking down column three of our table, with this law in mind, it is easy to reason why some petroleum vapors are heavier than others, for any number of large molecules should be heavier than any equal number of small ones, and they are. This knowledge is simple and interesting and shows an intelligent relation of the different members with their places in the columns of our table.

Observe the weights and boiling points of the various members in connection with the relative sizes of their molecules and this will enable us to think more intelligently as we proceed, for in this problem of tank protection we need as much knowledge and do as little guess work as possible.

The fourth column compares the weights of the various petroleum gases with air. The second member, Ethane, in gas form is the same weight as air, while Methane gas is only half as heavy, and all of the others are heavier than air and much heavier, but this is what you would expect after looking down columns two and three. Where there is no air circulation the heavier gases may lie around in pockets for some time or flow along the lower surfaces like water and they can be poured from one dish into another, so we can see how it is possible to arrange conditions so the heavier vapors might be the more dangerous, although this is very improbable outside of confinement, or in free air, and our tank menaces are seldom associated with that class.

The fifth column discovers the causes of our tank troubles. This column shows the temperature at which each member, if separated from the others, will rapidly become gas. It should be observed, however, these boiling points only hold true when the members are separated from each other and not when mixed together. Pure Methane liquid in a vessel would boil and become gas at 263 degrees below zero, Fahrenheit. In this respect it is not unlike liquid air, but when mixed with the other petroleum members in a large tank a small percent of it may be held in solution for some time at a temperature far above its own boiling point. The same is true of Ethane, Propane and Butane, but all of these attempt to get out as quickly as possible, especially on a warm day, for they are all gases and not liquids at natural temperatures.

It follows, therefore, that new oils are richer in the lighter hydro-carbon members and consequently a more serious lightning hazard than oils that have been exposed to evaporation for a longer period of time.

INFLAMMABLE CONDITIONS AND WHAT HAPPENS AT TANKS

These hydro-carbon gases are neither inflammable nor explosive unless mixed with air, and the ratio of this mixture is very interesting, especially if lightning is in the neighborhood. One per cent of petroleum gas mixed with air is not inflammable. One and one-half per cent will burn feebly. Two per cent to five per cent is sharply explosive, and more than six per cent is too rich in hydro-carbons to be explosive, but is, of course, inflammable where it blends into a thinner mixture. When air gas within a tank is too rich to explode it might burn around the edges of the roof for some time until it had burned an opening sufficient to let in enough air to dilute the mixture, when away might go to the top of the tank.

In warm weather the mixture of gases within a tank which contains a good per cent of the lighter fractions, is always explosive or inflammable, but these gases are seldom if ever either explosive or inflammable at much distance apart from a tank, as we shall presently show, and the solution of our fine problem is related only to the vapors in **immediate contact** with the tank and **no where else.**

The preconceived opinion that tank fires result from inflammable vapors high in the air is not founded on intelligent calculation. The factors of evaporation and diffusion are not scientifically considered with reference to a free atmosphere such as surrounds a storage tank, but rather with conditions such as might exist within an enclosure, and no successful system of tank protection can be established on such erroneous principles.

A RULE AND A PROBLEM

Here is a simple little rule which will help to square us with the facts. "A cubic inch of volatile petroleum will make a cubic foot of gas, and this cubic foot of gas will render 70 cubic feet of air slightly combustible." With this rule we may do some scientific calculation and less guess work, so let us try it on a practical problem.

Problem:—A 55,000 barrel tank during the heated season in Oklahoma will evaporate about fourteen barrels of volatile petroleum a day. How much confined air would that make inflammable?

Solution:—Fourteen barrels of petroleum are equal to 141,428 cubic inches and that multiplied by 70 equals almost 10,000,000, which would represent the maximum number of cubic feet of inflammable air it could produce. This is equal to an enclosure 215 feet square and 215 high, or it would equal the volume of a cylinder the diameter of which equals that of the tank retaining earth wall and 200 feet high.

This, of course, applies to confined air such as would be in a room with no open doors or windows, as the law of diffusion would not permit gases to collect in this way in a free atmosphere, even if there was not a breath of wind.

Any air movement less than three miles an hour is a calm. Suppose, however, the wind should be blowing only one mile an hour, in that event the first vapors from our fourteen barrels would be in the adjoining county before the last vapors left the tank and the rest would be scattered all along the way and diffused in every direction. But the weather bureau tells me the average velocity of the wind in Oklahoma is 13 miles an hour and more during thunder storms, so what would that do to our vapors as they left the tank and where in the light of reason could you find a one and one-half per cent, or inflammable mixture very far from the tank?

THE ARDMORE DISASTER

The Ardmore Disaster in September, 1915, was caused by the escape of more than 500,000 cubic feet of vapor and spray within a few minutes, and all of this from one hole in a tank car. But that is more vapor than ordinarily would escape from a 55,000 barrel

tank in a week, and if this had taken an hour to escape, instead of a few minutes, there would have been no disaster at Ardmore, as the vapors would have been scattered over many miles instead of a few blocks.

Flowing wells give off vapors much more profusely than do storage tanks and might create an inflammable region for some rods on a calm day, but never so far on a windy day because of more rapid diffusion.

If all of the vapors that ordinarily escape from a flowing well in six hours could be released in a few minutes that would create a condition in its locality akin to the condition at Ardmore when 125 barrels of casinghead suddenly vaporized from a transit car when the pressure was released. Nothing approaching this, however, is possible in the evaporation from a storage tank in free air under any conditions, and all such thoughts should be dismissed.

VAPOR TESTS AT TANKS

In August, 1912, the writer tested many samples of air gas from the region of very volatile petroleum in storage and was unable to get an inflammable mixture six inches outside of any tank at any place on any of these days. This does not means there are never inflammable vapors outside of a tank for a much greater distance, for there surely are, but under any conditions the inflammable range is far within the limits of popular belief.

PETROLEUM GAS A VERY POOR CONDUCTOR OF ELECTRICITY

Gases of every kind under normal conditions are very poor conductors of electricity but none are poorer in this quality than petroleum.

The author finds in laboratory tests that a lightning discharge will ignore an ascending stream of petroleum vapor and make a path between the experimental cloud and tank quite apart from the vapor stream.

A burning petroleum tank, however, endangers neighboring tanks because flame is a very good conductor of electricity and ionizes the air to a great height. This might cause lightning discharges there that otherwise would not occur, which would cause electro static sparking on neighboring tanks with wooden roofs or roofs covered with loose sheet metal.

A burning petroleum tank could hardly cause a fire in a neighbor tank from its own flames unless the flames could reach the neighbor, because of the rapid diffusion of petroleum gases in free air.

EPITOME

We may summarize the foregoing in the following fourteen points:

ONE

All lightning tank fires are in one way or another due to tank roof conditions. Knowledge of these conditions is essential to tank protection.

TWO

The electrical charge of that part of the earth electrical field occupied by the tank is all on the upper surface of the tank roof. This charge is gradually acquired by the inductive action of a growing charge on a cloud and bound by the influence of the electrified cloud till released.

THREE

A lightning flash is the result of the discharge of the electricity from both the cloud and the earth electrical field. This discharge suddenly releases the bound charge on all tank roofs at that instant. The danger to the tanks is dependent on how this released charge gets off the roofs.

FOUR

The danger to wooden roof tanks or a roof covered with sheet metal is in the loose contacts of the various sheets of metal and the imperfect electrical contacts of the roof to the tank. Electrostatic sparks are liable to occur at loose metallic contacts when the bound charge on the roof is released by a lightning discharge at the tank or in the vicinity.

FIVE

The secret of safety in steel roofed tanks is the well riveted sections of the roofs and the well riveted roof to their tanks. This permits all parts of the roofs to discharge without electrical resistance. A properly connected steel roof with closed winch box should make a tank as free from lightning danger as is a railway car or a steel structural building.

SIX

A tank should be kept free from line wires as these greatly increase the danger zone. This is especially true of a tank with loosely connected sheet metal sections on the roof and poor electrical contact of the roof with the tank. A tank roof should also be kept free from vent pipes of any description, extending upwards, as such vent pipes or chimneys invite an electrical discharge at the very spot where the inflammable vapors are escaping.

SEVEN

The extended metallic pipe connections of a storage tank throughout the earth electrical field intensify electrostatic sparking at a tank roof, at the instant of a lightning

discharge anywhere within that field. Additional metallic groundings of the tank could do little extra harm and have no beneficial results whatever.

EIGHT

Sealing of tank roofs should be governed by scientific knowledge of the causes of tank fires, otherwise the tank is endangered.

NINE

The richer the air gas within a tank the greater the fire hazard from electrostatic sparks at the edge or on top of the roof. Sparks that could ignite some tanks could not ignite some others, because of the gas mixture, but the stronger the spark, the surer the fire in either case.

TEN

The region of inflammable air gas surrounding any storage tank is limited to a very narrow zone and the danger from electrostatic sparks is outside and in contact with the tank, as sparks cannot occur within a tank nor away from its exterior surface. A direct lightning stroke at a tank, however, would be a dangerous thing within this narrow zone.

ELEVEN

An open winch box on a tank roof establishes a serious condition around the region of the head of the stair railing during local thunder storms. This is especially true of a tank that is tightly sealed. No system of protection could save a tank under such conditions if a flash of lightning occurred at the top of the stair railing.

TWELVE

A storage tank is specially subject to St. Elmo's fire because of its extensive metallic earth connections. Laboratory experiments prove beyond any question that wooden roofed tanks could take fire at their roof connections from this cause. Steel roof tanks would not be affected.

THIRTEEN

Unless the metallic reinforcing and other metallic structural work of a concrete reservoir are properly connected together and to earth before the concrete is shot on, little could be done afterwards to protect the reservoir from electro static sparks. It should be a safe container if properly connected.

FOURTEEN

The West Dodd Tank Protection System is designed to neutralize every sparking possibility on the tank roof. This is accomplished by bringing every sheet of metal on the roof into perfect electrical union with the system, which has electrical connection to the tank rim every few feet. It would be impossible for an electrical charge to leave the roof except through the system and the roof is thus discharged without resistance, the same as is a steel roofed tank.

Special Scientific Demonstration

The author is the originator of the thunder storm machine and can demonstrate electrically.

EVERY PRINCIPLE ENUMERATED IN THIS BOOK TOGETHER WITH THE DISCHARGE OF THE EARTH'S ELECTRICAL FIELD

Showing Electro Static sparking on improperly arranged tank roofs situated within the electrified earth area.

PIPE LINES

Showing the serious electric influence pipe lines extending into the earth's electrical field have upon the tanks to which they are connected at the instant of a lightning discharge anywhere near these lines.

SAINT ELMO'S FIRE

Showing the Brush Electrical Discharge from a tank under the influence of a charged cloud and a possible cause for some tank fires without lightning resulting at the instant.

THE OPEN WINCH BOX

Showing a direct lightning flash at the stair railing and setting the tank on fire from the gases escaping from the winch box.

NO BRANCH LIGHTNING

Showing an electric condenser will only discharge in one place within a region connected up with pipe lines such as would be at any tank farm.

THE WEST DODD PROTECTION SYSTEM

Showing how and why it will prevent electro static sparking on a tank roof and the necessity for proper diagnosis to determine tank conditions.

REMARKS

The Scientific principles mentioned in this book have a wonderful meaning to the nation as well as to the petroleum industry and should not be conjured and discounted in the field by a novice who has little or no knowledge of the nature of electro static discharges.

These principles as related to petroleum storage tanks have been developed and worked out by the author during years of study in the field and in the laboratory.

Every feature associated with thank protection is scientific and special in the highest degree and not to be juggled by pseudo scientific men incompetent to judge of tank dangers during lightning discharges.

The author is ever ready and willing to discuss, demonstrate and elucidate these principles with scientific men or any who may be sincerely interested, free of expense and without obligation.

Address: The West Dodd Tank Protection Co., Des Moines, Iowa.

REFERENCES

The following references may be interesting to any who seek scientific knowledge along some of the lines we have endeavored to simplify:

"THE DISCHARGE OF THE EARTH ELECTRICAL FIELD"

Consult "On the Sign and Magnitude of Electric Discharges in Lightning Flashes," by C. T. R. Wilson, M. A., F. R. S., observer in Meteorological Physics at the Solar Observatory, Cambridge, England, fully discussed in the Proceedings of the Royal Society A Vol. 92, 1916, pages 555 to 574. Also in bulletin form.

This master scientist discovered and describes a means to determine the volt meter variations at any place within the earth electrical field at the instant of a lightning discharge, whether near or far.

Can be obtained through the Scientific American or D. Van Nostrand Co., 25 Park Place, New York.

"THE BRUSH ELECTRICAL DISCHARGE"

See "Experimental Researches on Electricity," Vol. 1, pages 454 to 472, by Michael Farady.

Also "Elementary Lesson in Electricity and Magnetism," pages 298 to 300, by Sylvanus Thompson.

CONCERNING "IONIZATION OF GASES"

Consult "Electrons," by Sir Oliver Lodge.

Also "The Discharge of Electricity Through Gases," by Prof. J. J. Thompson.

DIFFUSION OF GASES

See Avogadro's Law. Found in any good work in Physics.

Also see "The Kenetic Theory of Gases," chapter 3, part 2, by C. E. Meyers. Also A. D. Risteen's "Molecules."

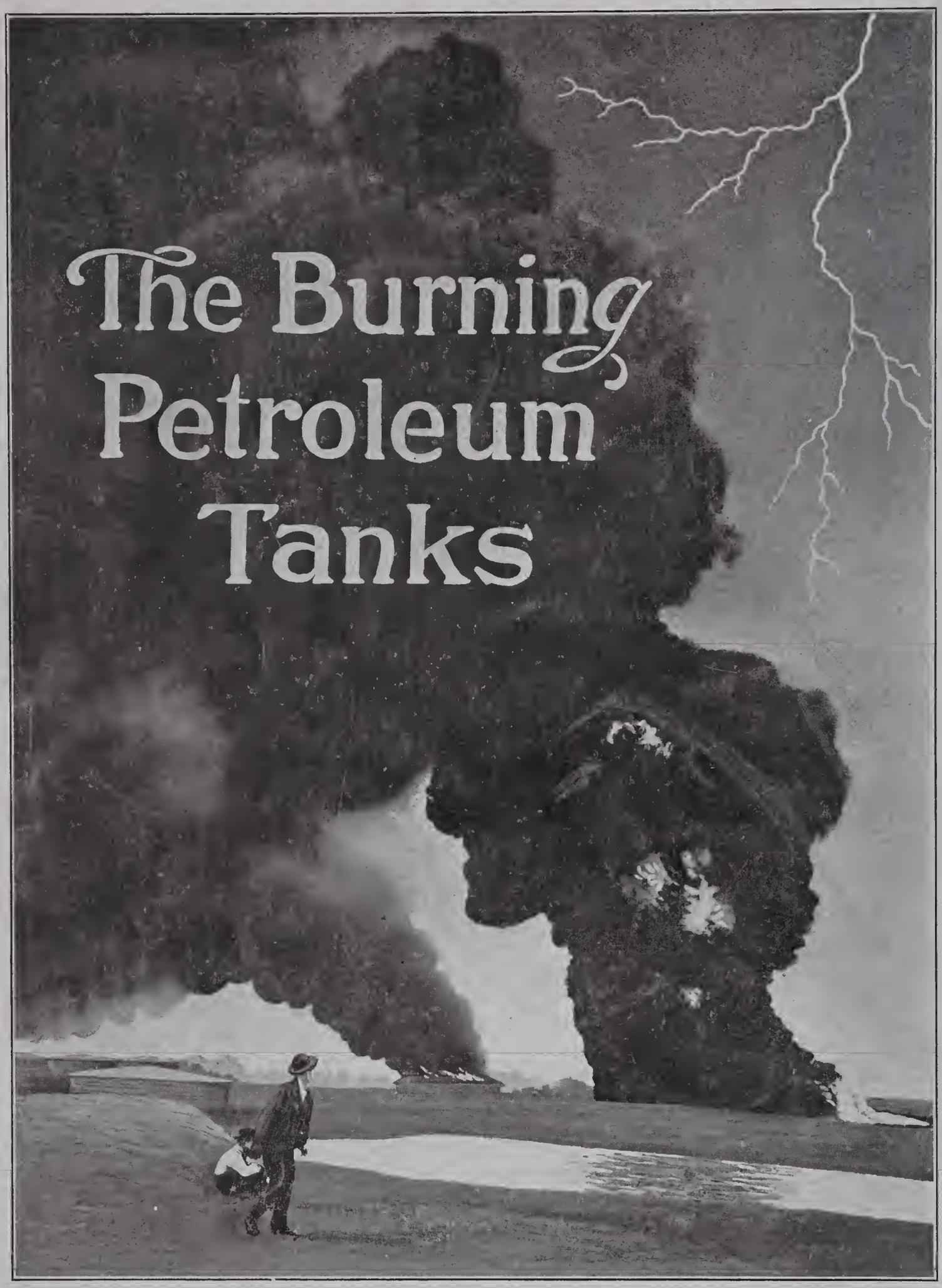
PETROLEUM GASES

Consult Boverton Redwood's "Treatise on Petroleum," Vol. 2.

This work is in three volumes and is very complete.

Questions relative to Lightning Protection to any kind of Property cheerfully and freely answered.

Address, WEST DODD, Des Moines, Iowa.


The Burning
Petroleum
Tanks